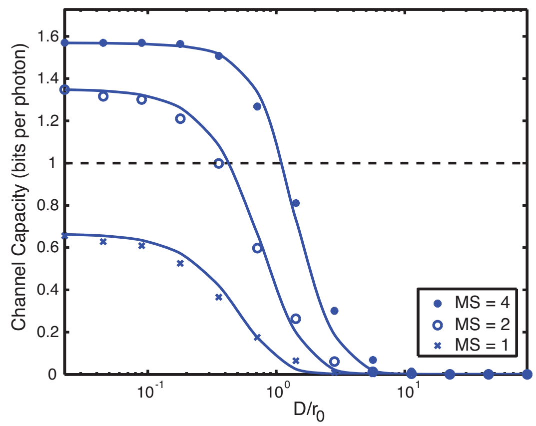

Fig. 5. Effects of changing the spacing between detected modes (MS) on the channel capacity of a 3-dimensional OAM communication system in the presence of atmospheric turbulence. For a mode-spacing of 4, the maximum channel capacity of a 3-dimensional system is seen to approach the theoretical maximum of $\log_2(3) = 1.585$.

crosstalk introduced by the sorter [15]. The theoretical channel capacity as calculated by Eq. (5) is plotted in Fig. 4, as well as the channel capacity of a polarization-based two-dimensional system, which is essentially immune to the effects of turbulence.

As can be seen, the maximum channel capacity for $N = 11$ is much lower than the theoretical maximum of $\log_2(11) = 3.46$ bits/photon. This is because the OAM sorter is not perfect and introduces some inherent crosstalk [15]. Nonetheless, our higher dimensional systems perform much better than the polarization-based system below a certain turbulence strength. This is indicated in Fig. 4 by the point at which the channel capacity curve for an N-dimensional system crosses the dotted line for a polarization-based system. At a turbulence strength of $D/r_0 = 10$, the channel capacity vanishes for all systems.

Since OAM modes constitute an infinite-dimensional basis, one can reduce the effects of the inherent sorter crosstalk and turbulence by increasing the spacing (MS) between detected modes to greater than one. We study this effect on a subset of our system with N = 3, for three different mode-spacings (MS = 1, 2 and 4). It is clear from Fig. 5 that increasing the mode spacing between detected modes boosts the initial channel capacity and makes our system slightly more resistant to turbulence. The maximum channel capacity for a mode-spacing of four is close to the theoretical maximum of $\log_2(3) = 1.585$. In addition, the channel capacity for this mode-spacing starts decreasing at a value of D/r_0 that is almost an order of magnitude greater than that for a mode-spacing of one.

4. Conclusions

We characterized the effects of Kolmogorov thin-phase turbulence on the channel capacity of an OAM-based communication system at high light levels. We found that turbulence affects the channel capacity drastically, and the effects can be mitigated by increasing the mode-spacing. We were not able to study the effects of thin-phase turbulence on the ANG channel due to the inherent limitations of our mode sorter. We are currently working on improving the performance of our mode sorter and extending our study to thick-phase turbulence. We would like to thank Dr. D. J. Gauthier for useful discussions. This work was supported by the DARPA/DSO InPho program and the Canadian Excellence Research Chair (CERC) program.

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